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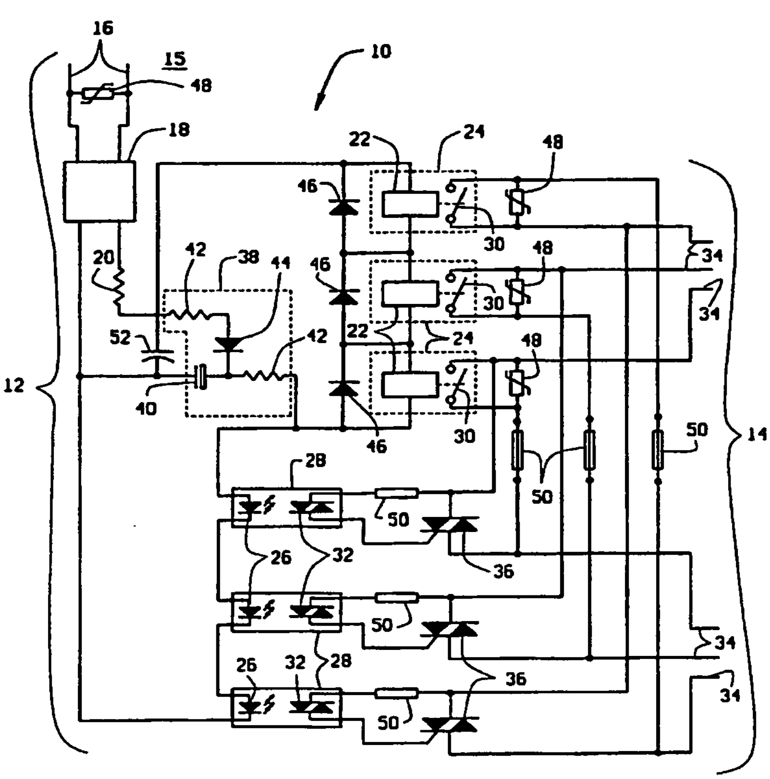
(54) Title: MERCURY-FREE ARCLESS HYBRID RELAY



(57) Abstract: A hybrid relay is shown for switching power combining the advantages of a mechanical relay and a solid state relay. The mechanical relay has lower heat dissipation and can remain in more compact packaging for that reason. The solid state relay carries the load side current during the leading and trailing edges of the power cycle to prevent arc. To overcome the deficiencies in the prior art, the mechanical relay and solid state relay are connected in series on the control side of the device. An optional charge reservoir may be used to counter the bounce effects in the mechanical relays when switching high current loads.

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MERCURY-FREE ARCLESS HYBRID RELAY

Field of the Invention

The present invention relates to power switching relays, and more particularly to a power switching relay that contains no mercury and produces no arc due to a hybrid combination of mechanical and solid state switches.

Background of the Invention

In the power area, mechanical relays have several practical advantages over other types of power control. Because of the low electrical resistance of metallic contacts, the on-state power dissipation of a relay is inherently low. This high on-state efficiency allows mechanical relays to be much more compact than solid state relays, which must dissipate 1 to 2 watts of power per switched amp of current. The chief limitation of mechanical relays is the degradation of the contact material caused by electrical arcing as the contacts make and break. Breakdown of the contact is the primary failure mechanism for mechanical relays.

Solid state based switching devices have a significant on-state voltage drop and as a consequence must dissipate 1 to 2 watts of power per switched amp of current, as mentioned above. This limitation of high power dissipation results in devices that are bulky and expensive. Additionally, the inherent power dissipation of these devices limits their application in environments where high ambient temperatures are encountered. There is also a resulting need for large and expensive heat sinks required to deal with this wasted energy, which is the inherent limitation for solid state switching techniques.

It has been known in the past to substitute mercury relays for mechanical relays. Being a liquid metal, mercury is less vulnerable to breakdown from arcing and had low power dissipation. However, mercury is a dangerous element, and the relays are subject to leaking. Many places have banned mercury relays in some applications, such as in food service environments.

It has also been known to solve the above problems by combining a solid state relay circuit in parallel with a mechanical relay contact switch. Most of these inventions use solid state triacs ("bi-directional thyristors") for this purpose. Some of the inventions use digital circuitry such as those shown in U.S. Patent 4,074,333 issued to Murakami et al., U.S. Patent 4,392,171 issued to Kornrumpf, and U.S. Patent 5,528,443 issued to Itoga et al. Thus, these inventions require an additional power source for the digital components.

Still other inventions have used optically coupled triacs to avoid the digital circuitry. U.S. Patent 4,855,612 issued to Koga et al., U.S. Patent 5,503,907 issued to Nishi et al., and U.S. Patent 5,283,706 issued to Lillemo et al. all show the use of optical coupling of a light emitting diode (LED) to a triac, thus eliminating the need for digital components. Nonetheless, the lack of digital components has also created imperfect timing. Each of these inventions uses one or more resistor-capacitor (RC) circuits to time the switching of the LED. As the control voltage is applied, the capacitor charges, causing voltage across the capacitor to increase. At a certain point after the control voltage is applied, current is forced through an induction coil, thus triggering the mechanical relay. When the control voltage is removed, the charge in the capacitor keeps the LED lit, thereby keeping the solid state relay active. At a certain point, as the charge dissipates the LED turns off, but not until the mechanical relay has had time to open.

The primary limitation of these devices is that the voltage in an RC circuit is an exponential function in relation to time, both as the circuit charges and discharges. This creates a lack of sharp or precise turn on or turn off times. This can also create "bounce" or "flutter" in the switched device, for instance when the gate voltage of a transistor is right at the rated voltage.

Most recently, Jamil Altiti and Keith Ness of Watlow Electric Manufacturing Company have shown in U.S. Patent 5,790,354 (having like ownership herewith) that is possible to overcome all of the above limitations by taking advantage of the inherent lag time in mechanical relays. Using only analog components, the optical triac is controlled by a precision trigger coupled to a pulse stretcher (such as a Schmitt trigger pulse stretcher). Yet there is still a demand for a more compact and simpler solution that still overcomes the same obstacles that Altiti and Ness did. Another limitation of this device is that it uses an inverted control voltage signal. Thus if the control voltage signal malfunctions, the relay could become stuck in an on-state.

It is therefore an object of the present invention to provide a mercury-free power switching relay that does not produce arcing with low power dissipation.

It is another object of the invention to provide such a power switching device with sharp switching on and off.

It is yet another object of the invention to provide such a device in as compact and as safe a device as possible.

Other objects of the present invention will become apparent from the specification described herein below.

Summary of the Invention

In accordance with the objects listed above, the present invention is a power switching device including a mechanical relay(s) and solid state relay(s) connected in series on the control side. The mechanical relay is of the conventional type, having a winding on the control side, which when energized, becomes magnetic to pull a physical switch closed on the load side. The solid state relay consists of a light emitting diode (LED) coupled to an optical triac.

The present invention is noticeably missing any sort of a timing circuit present in prior art arcless switching devices due to the fact that relays are connected in series. This makes the present switching device the simplest arcless power switching device to date, increasing reliability while simultaneously decreasing size and cost. The present invention accomplishes the proper switching order by careful selection of both the mechanical and solid state components.

An opto-triac (the LED and optical triac combination) is selected with a very low switching threshold, for instance an opto-triac could be selected having an "on" state with as little as 1.5 mA of current through the LED. On the other hand, a mechanical relay is chosen that requires perhaps between 25 mA and 60 mA of current though the winding before it is sufficiently magnetized to pull the switch closed ("pickup threshold"). That same mechanical relay, for example, might have a dropout threshold (the level of current reached before the contact switch is released to the open position) of between 10 mA and 35 mA. The resulting effect without a timing circuit is that when the control signal is applied, the opto-triac turns on first (with an additional boost from the inherent delay in a mechanical relay). Similarly, when the control signal is turned off, the mechanical switch has opened while there still enough current in the circuit to keep the opto-triac "on".

The load side is still connected in parallel, as with prior art arcless switching devices, so that when the mechanical relay is closed its lower resistance carries nearly all of the load current. Thus, the solid state relay only carries a significant load current on the leading and trailing edges of a switching cycle. Therefore, very little heat must be dissipated from the solid state relays.

Because the present device has no timing circuit, is compact, and requires no low voltage secondary power supply, it can be used as a drop in replacement for existing mechanical relays. Furthermore, like its predecessors, the prevention of arcing greatly prolongs the life of the device without the use of mercury.

Optionally, the present invention may also contain a charge reservoir to supply a small amount of additional current to the solid state relay after the control signal is turned off. This is useful in situations involving high load currents, where the high current through the mechanical switch can cause bouncing of the switch, and therefore delay the time until the mechanical switch is completely open. The present device will still function without the charge reservoir or if the charge reservoir fails, however a small amount of arcing may be present on the trailing edge of the switching cycle in instances of high load current.

Brief Description of the Drawings

The above-mentioned and other features, advantages and objects of this invention, and in the manner in which they are obtained will become more apparent and will be best understood by reference to the detailed description in conjunction with the accompanying drawings which follow, wherein:

Fig. 1 is a schematic diagram of the circuit, which embodies the present invention; and

Fig. 2 is a waveform diagram showing the timing operation of the components included in the present invention.

Detailed Description of the Invention

Referring now to Fig. 1, an arcless hybrid power switching device (relay) 10 is shown generally. The switching device consists of a control side 12 and load side 14. The control side has a single input 15 received through the two input leads 16. The device can easily be made to accept a direct current (DC) control input, however in real world situations, an alternating current (AC) control input is more common. Therefore a full-wave bridge rectifier 18 is provided to convert the AC control input to a DC control signal. An optional resistor 20 is provided to match the working input voltage to the appropriate range.

The primary components of the control side 12 are the windings 22 of the mechanical relays 24 and the LEDs 26 of the opto-triacs 28. Note that the figure shown is for three-phase power switching, however the invention works equally well for single-phase power switching by simply reducing the number of mechanical relays and opto-triacs to one each. All other components on the control side 12 are optional and will be discussed in further detail below. On the control side, the windings 22 of the mechanical relays 24 and the LEDs are connected in series.

The mechanical relays 24 are chosen to have a significantly higher switching rating on the control side 12 than the opto-triacs 28. For instance, a mechanical relay may be chosen that switches on when the winding is subject to a control current of greater than 25 mA (with a dropout threshold of 10 mA), while the corresponding opto-triac may be rated to be switched on when the LED is subject to as little as 1.5 mA. Choosing a mechanical relay with a higher current switching

rating on the control side is vital to make the present invention work. Furthermore, components should be chosen with small tolerances on the current switching rating.

On the load side 14, the primary components are the switches 30 of the mechanical relays 24 and the triacs 32 of the opto-triacs 28. These components are connected in parallel on the load side 14. The load side 14 will have either two output leads 34 for single-phase power or six output leads 34 for three-phase power. The load side will also typically have a secondary triac 36 for each opto-triac 28. These secondary triacs 36 are provided as electrical shunts on relay output contacts.

When the control input 15 is statically absent, there is no current through the mechanical relays 24, nor the opto-triacs 28. When the control input 15 is turned on at t_0 (as can be seen in Fig. 2), a current quickly builds up in the circuit of the control side 12. Immediately following that (nearly instantaneously), at t_1, the current in the circuit reaches the switching threshold for the opto-triac 28 (1.5 mA for example). At that time, the LED 26 goes on, the triacs 32 and 36 switch on, and the load side 14 begins conducing power through the triac 36 (or 32 in embodiments not containing triacs 36). A very short time after that, at t_2, the current reaches the threshold for the mechanical relay 24 (25 mA for example), closing the switch 30. At that time, substantially all of the current on the load side 14 begins flowing through the switch 30 which has only negligible resistance compared to the triac 36. For three-phase power, of course, this process occurs simultaneously for all three load side circuits.

The load side 14 remains energized until after the control input 15 is turned off at t_3. At that time, the current in the control side 12 circuit rapidly decreases. When that current reaches the threshold for the mechanical relay 24 (10 mA for example) at t_4 the switch 30 opens and the load side current is again carried by the triac 36. The residual current in the control side 12 keeps the LED 26 energized for a very

short time longer, but just long enough to allow the switch 30 to open without arcing. Finally at t_5 the current in the control side 12 falls below the switching threshold for the opto-triac 28 (2 mA for example) and the load side 14 becomes completely deenergized.

In instances where the load being controlled draws a particularly large current, the switch 30 may have a tendency to bounce. To counteract the bounce effect, an optional charge reservoir 38 may be added. The charge reservoir 38 primarily comprises a capacitor 40, but may also include resistors 42 and diode 44 to prevent the reservoir 38 from energizing the mechanical relay 24 as well. After the control input 15 is turned off, the capacitor 40 begins releasing the charge is stored during the "on" time of the power switching cycle. This slightly extends the energized cycle time (the exact amount depending upon the capacitance of the capacitor 40) of the opto-triac 28, allowing it to compensate for the bounce in switch 30.

Other optional components in the circuit include a capacitor 52 which acts line voltage filter, diode(s) 46 selected to absorb back EMF generated by the winding 22 of the mechanical relay 24, and various transient voltage suppressors 48 and current limiters 50 for safety and to protect the various components of the device. The addition of these optional components are illustrated only for the purpose of demonstrating the best mode of practicing the invention.

Accordingly, while this invention is described with reference to a preferred embodiment of the invention, it is not intended to be construed in a limiting sense. It is rather intended to cover any variations, uses or adaptations in the invention utilizing its general principles. Various modifications will be apparent to persons skilled in the art upon reference to this description. It is therefore contemplated that

the appended claims will cover any such modifications or embodiments as fall within the true scope of the invention.

Claims

I claim:

1. A mercury-free arcless hybrid relay comprising:

a load circuit adapted to couple to a load and a load power source;

a mechanical relay having a contact switch and a magnetic coil winding, said contact switch operatively coupled to said load circuit, said winding closing said contact switch when an electric current is applied thereto;

a solid state relay having a semiconductor triac optically coupled to a light emitting diode, said semiconductor triac effectively having a first terminal electrically coupled to one side of said contact switch and a second terminal electrically coupled to the other side of said contact switch, said light emitting diode being coupled in series with said magnetic coil winding;

a control voltage signal, wherein said winding and said light emitting diode adapted to receive said control voltage signal, said control voltage signal causing said winding and said light emitting diode to be energized when present and said control voltage signal causing said winding and said light emitting diode to be deenergized when absent; and

wherein electrical current is eliminated from the load when both said contact switch is open and said light emitting diode is deenergized.

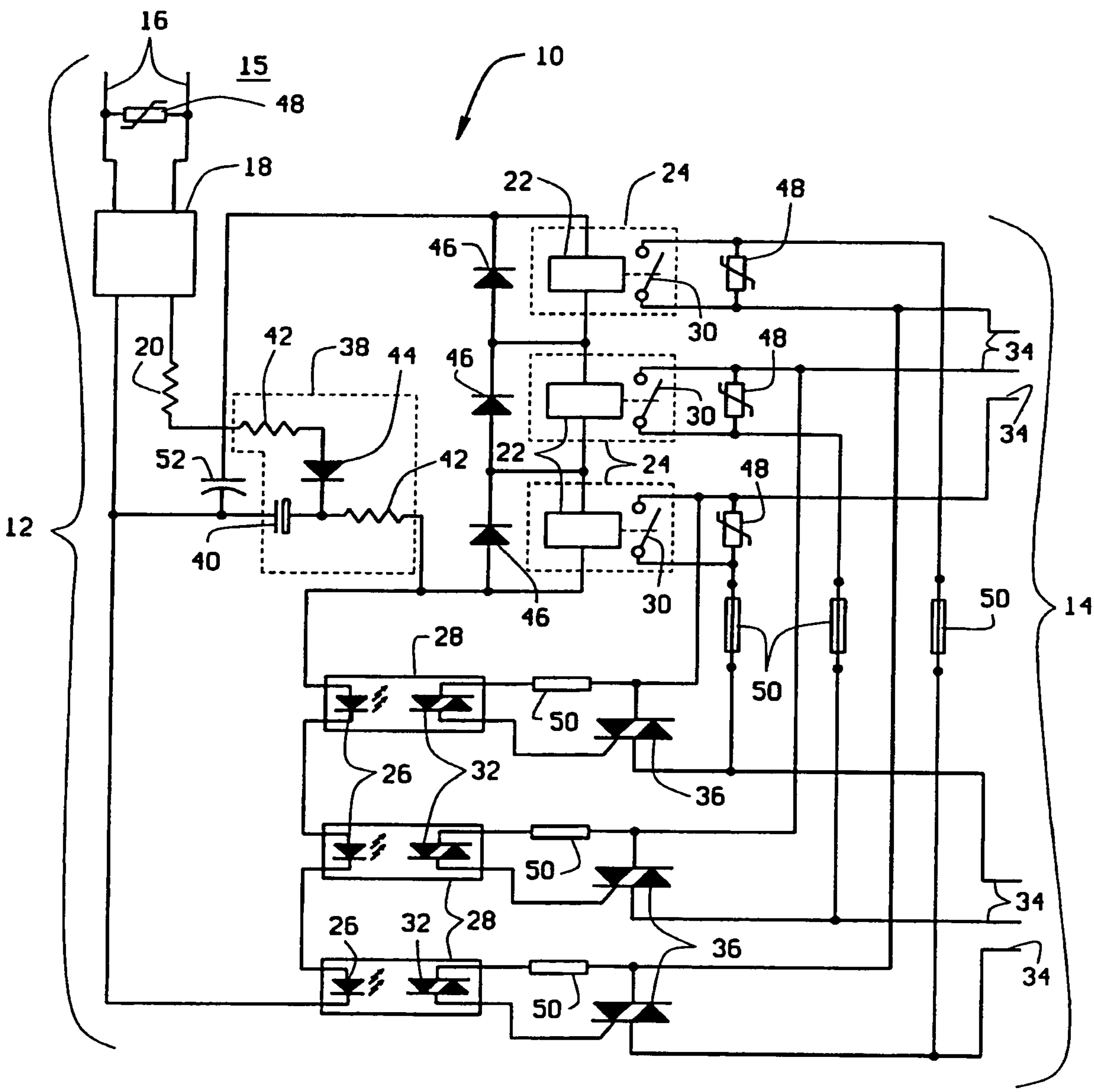
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FIG. 1

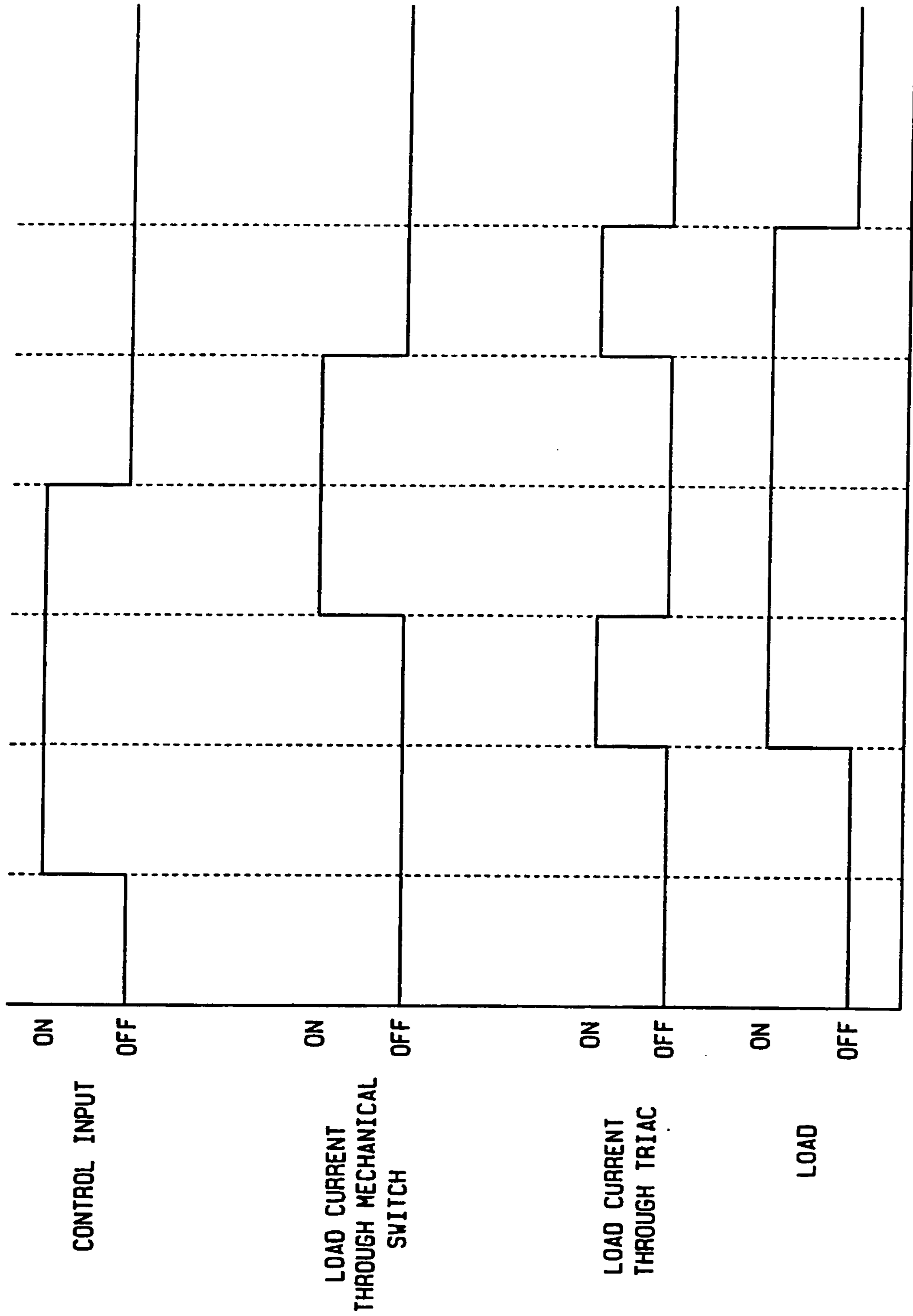
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FIG. 2